A. COVER SHEET

Water Use Efficiency Program
Proposal Solicitation Package

1. Specify: agricultural project or urban project; individual or joint application

2. Proposal Title: **Improving Procedures for Tuning Controllers for Automatic Downstream Water Level Control of Canals to partially address all of the CALFED Quantifiable Objectives**

3. Principal applicant: **California Polytechnic State University**
Irrigation Training and Research Center

4. Contact: **Dr. Stuart Styles**
Director

5. Mailing Address: **Dr. Stuart Styles - BRAE/ITRC**
Cal Poly State University
1 Grand Avenue
San Luis Obispo, CA 93407

6. Telephone: **(805)756-2429 (direct) (805)756-2434 (office)**
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8. E-mail: **sstyles@calpoly.edu**

9. Funds requested: **$38,972**
10. Cost Share: **$20,000**

11. Duration: **June 2001 to June 2002**

12. State Assembly/Senate districts and Congressional Districts where project is to be conducted:
Affects all portions with irrigation districts which have potential to use automated downstream control in CA

13. Location and geographic boundaries of the project: **State of California**

14. Name and signature of official representing applicant. By signing below, the applicant declares the following:
- the truthfulness of all the representations in the proposal;
- the individual signing the form is authorized to submit the application on behalf of applicant;
- the applicant will comply with contract terms and conditions identified in Section 11 of the PSP.

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B. SCOPE OF WORK

1. Abstract

The goal of this project will be to improve the procedures for automating canals with downstream water level control. This will in turn enable irrigation districts to provide more flexible and reliable deliveries to the farm at greater safety and lower cost. A procedure will be developed to filter water level signals in the software of the control logic. The procedure will incorporate theory from advanced control logic developed in the Netherlands. There is a need to improve the understanding of the tuning of local downstream control, whether it is for pumps or check structures. A better procedure will allow for much quicker and better assistance to irrigation districts as they attempt to modernize their irrigation canals. This project will address and solve these deficiencies.

2. Statement of Critical Issues

Most canal systems operate under manual upstream control. Flow rates into the canals are adjusted at least daily, based on known deliveries downstream. The nature of upstream controls is that the inflow never exactly balances the desired outflow, so there are always either (i) spills, (ii) shortages, or (iii) water level fluctuations in the canals.

Downstream control has the benefit of being able to supply water on a "demand" basis. If users increase or decrease their flows, the canal control (either pumps or check structures) automatically senses the change in demand and releases the correct change. There is very little downstream control of canals in California, but the inherent advantage of downstream control makes it quite appealing.

For many years downstream control was more in the realm of "theory" rather than practice. With the development of reliable SCADA (Supervisory Control and Data Acquisition) systems, good sensors, excellent Programmable Logic Controllers, and new canal modeling techniques, there is suddenly considerable interest in actual practical application. Under the USBR (Mid-Pacific Region) technical assistance program, ITRC has modeled canals for Patterson ID and Reclamation District 108 for successful application of downstream control. Previously, Patterson ID has a downstream control system that only operated a few hours before it needed to be shut down because of instability problems.

There are certain constraints to downstream control, such as the need for minimum pool storage. Therefore, it is not applicable on very steep and narrow canals. But in the San Joaquin Valley of

California, there are many canals with potential application. In the past, ITRC has helped Patterson ID automate 3 pools of its main canal, and will soon begin to assist Banta Carbona ID and West Stanislaus ID on their applications.

Despite the successful application in Patterson ID, ITRC realizes that its procedures for tuning the controller parameters must be improved. Presently, the tuning procedure that leaves little time to examine other control logics, and which simply takes too long to obtain a good solution. Furthermore, ITRC's procedure does not address filtering of potential unstable resonance frequencies in the control logic.

The beneficiaries are first the irrigation districts. If they can provide automatic demand deliveries in their main canals, they will be able to provide much better service (more flexibility and reliability) with less labor. Furthermore, the incidences of spillage and canal damage should be reduced.

The second set of beneficiaries is the farmer within the irrigation districts. They must modernize their on-farm irrigation systems and practices, and in order to achieve this they must have more flexible irrigation deliveries. While this project will primarily focus on main canal automation, many main canals supply pipeline systems and direct turnouts that could be operated on a "demand" basis if the main canal is operated with downstream control.

This project directly addresses Efficient Water Management Practice 9 (EWMP9). EWMP 9 is the practice to "automate canal structures".

3. Nature, scope, and objectives of the project

There is a need to improve the understanding of the tuning of local downstream control, whether it is for pumps or check structures. A better procedure will allow for much quicker and better assistance to irrigation districts as they attempt to modernize their irrigation canals.

The use of downstream control as a modernization tool can decrease (i) spills, (ii) shortages, or (iii) water level fluctuations in the canals improving district service and efficiency.

A mathematical procedure will be developed to determine optimum stable control constants for local downstream control for 3 cases: (1) control point immediately downstream of the gate or pumps, (ii) at the distant downstream end of a pool, and (iii) at an intermediate point within the pool.

Presently, Proportional-Integral-Derivative (PID) logic is used by ITRC for the automatic controller. Other types of logic will be investigated for suitability with downstream control, using local distributed controllers.

Dr. Burt is in continual contact with others working on the subject of canal automation and control. Therefore, there is no "learning curve" or any need to do a literature search as part of this project – the state of the art is already well understood. This project will provide significant improvements to previous work on the subject of downstream control, enabling ITRC and others to considerably decrease the time necessary to automate individual canals.

4. Methods, procedures, and facilities

The project will be conducted by the Irrigation Training and Research Center (ITRC) at Cal Poly. Dr. Charles Burt will be the project director.

The following tasks will be completed:

1. A procedure will be developed to filter water level signals in the software of the control logic. At present, no filters are used. In some cases, filters are necessary to eliminate the possibility of instability of control. The procedure will incorporate theory from advanced control logic developed in the Netherlands.

2. A mathematical procedure will be developed to determine optimum, stable control constants for local downstream control for 3 cases: (i) control point immediately downstream of the gate or pumps, (ii) at the distant downstream end of a pool, and (iii) at an intermediate point within the pool (such as at Patterson ID).
3. Presently, Proportion-Integral-Derivative (PID) logic is used by ITRC for the automatic controllers. Other types of logic will be investigated for suitability with downstream control, using local distributed controllers.

Dr. Burt is in continual contact with others working on the subject of canal automation and control. Therefore, there is no "learning curve" or any need to do a literature search as part of this project – the state of the art is already well understood. This project will provide significant improvements to previous work on the subject of downstream control, enabling ITRC and others to considerably decrease the time necessary to automate individual canals.

Deliverables: The project will produce a brief report that summarizes new findings and procedures. In addition, the new findings will be applied to the work at West Stanislaus ID canal modernization.

This proposal is an action-specific proposal that incorporates actions that will address all of the CALFED Quantifiable Objectives. The proposed Technical Services will help districts with the implementation of projects that will reduce true irrigation system losses.

5. Schedule

It is anticipated that the funds would be spent within one year with the majority of the funds (over 75%) being spent during the summer of 2001.

6. Monitoring and Assessment

It is anticipated that the expertise provided to the irrigation districts proposed in this project will help irrigation districts with their ultimate decrease in available water supplies.

C. OUTREACH, COMMUNITY INVOLVEMENT, AND INFORMATION TRANSFER

1. Outreach

The technical services will be provided to the West Stanislaus Irrigation District and will help support other districts that traditionally have not been able to afford for irrigation professionals to evaluate the district operations. Some irrigation districts have been set up and operated for almost 100 years with a simple, yet flexible water supply. These districts will be the ones most impacted with tightening water supplies.

2. Training, Employment, and Capacity Building

The ITRC proposal will provide training to irrigation district personnel. It is estimated that about 400 persons receive training every year. The ITRC employs 30 persons. About 20 of these are students who are provided with an excellent opportunity to receive professional engineering training. This proposal will directly increase the base of students trained in irrigated agriculture who will contribute professionally after graduation in improving water management in California.

3. Information Dissemination

The project will produce a brief report that summarizes new findings and procedures. In addition, the new findings will be applied to the work at West Stanislaus ID canal modernization.

D. QUALIFICATIONS

1. Resumes

The resumes for Dr. Charles Burt and Dr. Stuart Styles are attached.

Pertinent Literature by Charles Burt and Co-authors.

"Regulation of Sloping Canals by Automatic Downstream Control." 1983. ASAE Paper No. 83-2582. Presented at the winter meeting of ASAE in Chicago, Illinois. C. Burt

"Canal Automation for Rapid Demand Deliveries (CARDD)." 1984. Proceedings of the ASCE Irrigation and Drainage Specialty Conference "Water Today and Tomorrow", held at Flagstaff, AZ. pp. 502-509. C. Burt

"Automation For Downstream Control On Small Irrigation Canals." 1986. ASAE Paper No. 86-2078. Presented at the summer meeting of the ASAE in San Luis Obispo, Calif. Ayers, Jonas, and Burt.

"Overview of Canal Control Concepts." 1987. Planning, Operation, Rehabilitation and Automation of Irrigation Water Delivery Systems. Proceedings of a Symposium in Portland sponsored by the I&D Div. of ASCE. Darell Zimbelman, Editor. pp. 81-109. C. Burt

"Water Delivery Control". 1989. Chapter 11 of the ASAE monograph "Management of Farm Irrigation Systems", to be printed in 1990. Burt and Plusquellec.

"Research Needs in Irrigation and Drainage - 1989. Journal of Irrigation and Drainage Engineering, Vol. 115, No. 4, Aug. 1989. By the ASCE Research and Education Administrative Committee. Contributing member.

"Canal Automation Providing On-Demand Water Deliveries for Efficient Irrigation." 1989. Final report for USGS Water Resources Research Program, Grant 14-08-0001-G1280. Burt and Parrish. NTIS Access No. PB90119769/AS.

"Irrigation District Canal Automation - CARDD". 1990. Proceedings of the Third National Irrigation Symposium. Phoenix, Arizona. ASAE Publication 04-90. pp. 495-500. C. Burt

"Canal Models and You". 1991. Proceedings of the National Conference on Irrigation and Drainage Engineering. Honolulu, Hawaii. ASCE. Burt and Gartrell.

"Unsteady Flow Modeling of Irrigation Canal". 1993. ASCE Task Committee on Irrigation Canal System Unsteady Flow Modeling. Journal of Irrigation and Drainage Engineering. ASCE 119 (4):615-630. ASCE. New York. Clemmens, et. al.

"Irrigation Canal - Simulation Model Usage". 1993. Journal of Irrigation and Drainage Engineering. Vol. 119 (4):631-636. Burt and Gartrell.

" Cal Poly Model Canal." 1993. Journal of Irrigation and Drainage Engineering. Vol. 119 (4):631-636. J. Parrish and C. Burt.

"Modern Water Control in Irrigation - Concepts, Issues, and Applications". 1994. World Bank Technical Paper Number 246. Irrigation and Drainage Series. The World Bank. Washington, D.C. Plusquellec, H., C. M. Burt and H. W. Wolter.

"Response of Ideally Controlled Canals to Downstream Withdrawals" 1995. Proceedings of the ASCE Water Conference in San Antonio, Texas (Water Resources Engineering). Burt, R.S. Gooch, T.S. Strelkoff, and J.L. Deltour. pg. 169-173.

"Introduction to Canal Control Algorithm Needs" 1995. Proceedings of the ASCE Water Conference in San Antonio, Texas (Water Resources Engineering). Clemmens, A.J., C. M. Burt, and D.C. Rogers. pg. 1-5.

Modern Water Control and Management Practices in Irrigation: Methodology and Criteria for Evaluating the Impact on Performance. 1996. Proceedings of the Expert Consultation on Modernization of Irrigation Schemes: Past Experiences and Future Options. Bangkok, Thailand. 26-29 Nov. Food and Agricultural Organization of the United Nations. C. Burt

Concepts for Irrigation System Modernization. 1996. Proceedings of the Expert Consultation on Modernization of Irrigation Schemes: Past Experiences and Future Options. Bangkok, Thailand. 26-29 Nov. Food and Agricultural Organization of the United Nations. Hans W. Wolter and C. Burt

“Essential Water Delivery Policies for Modern On-Farm Irrigation Management.” 1996. Irrigation Scheduling: From Theory to Practice. Water Reports No. 8. Food and Agriculture Organization of the United Nations. Rome, Italy. pp. 273-278. C. Burt

“Influence of Canal Geometry and Dynamics on Controllability”. 1998. Journal of Irrigation and Drainage Engineering. ASCE 124(1): 16-22. Strelkoff, Deltour, Burt, Clemmens, and Baume.

“Improved Proportional-Integral (PI) Logic for Canal Automation”. 1998. Journal of Irrigation and Drainage Engineering. ASCE 124(1): 53-57. C.M. Burt, R.S. Mills, R.D. Khalsa, and V. Ruiz C.

"Modern Water Control and Management Practices in Irrigation: Impact on Performance". 1998. Information Techniques for Irrigation Systems (ITIS5). International Meeting on Modernization of Irrigation System Operations. Aurangabad, Maharahstra, India. Oct. 28-30. pp. 62-79. Burt and Styles.

"Modern Water Control and Management Practices in Irrigation. Impact on Performance". 1999. Water Reports #19. 224 p. Food and Agriculture Organization of the United Nations. ISSN 1020-1203. ISBN 92-5-104282-9 C.M. Burt and S.W. Styles

"Case Study: Modernization of the Government Highline Canal". 1999. Proceedings, Modernization of Irrigation Water Delivery Systems. 1999 USCID Workshop in Phoenix, AZ. October 17-21. S. Styles, C. Burt, R. D. Khalsa, and R. Norman. pp. 187-202.

"Case Study: Modernization of the Patterson Water District". 1999. Proceedings, Modernization of Irrigation Water Delivery Systems. 1999 USCID Workshop in Phoenix, AZ. October 17-21. S. Styles, C. Burt, M. Lehmkuhl, and J. Sweigard. pp. 647-662.

2. External Cooperators

External cooperators scheduled for this program:

Dr. Jan Schuurmans
Consultant, The Netherlands

Dr. Schuurmans is a specialist in the mathematics of canal automation. He will visit ITRC as part of the project budget, but most of his work will be via e-mail.

Peter-Jules van Overloop
Consultant, The Netherlands

Mr. van Overloop is a specialist in control theory, especially with matters of signal filtration and resonance. He will visit ITRC as part of the project, but most of his work will be via e-mail.

Dr. Xianshu Piao
Control specialist, ITRC

Dr. Piao will be a visiting scholar. She has a background in automatic controls

3. Partnerships

A portion of the work has been funded and cost shared by a California Energy Commission grant to ITRC, under which ITRC will improve its procedures for tuning upstream (as opposed to downstream) controllers.

E. COSTS AND BENEFITS

1. Budget Summary

The following is the estimated breakdown of the budget for 1 year. The total amount requested is **$38,972.**

	Year 1
Salaries and wages	$13,501
fringe benefits	$3,820
supplies	$6,459
equipment	$0
travel	$5,000
consultants	$8000
other (direct costs)	$6,750
total	$38,972

The work on MatLAB solutions (mathematical optimization routines) and signal filtering will be cost shared by a California Energy Commission grant to ITRC, under which ITRC will improve its procedures for tuning upstream (as opposed to downstream) controllers. Cost sharing will be approximately **$20,000.**

2. Budget Justification

Salaries and overheads used in developing this cost estimate were based on existing contracts with the USBR and California Energy Commission and the Cal Poly ITRC.

3. Benefit Summary

The first beneficiaries are the irrigation districts. If they can provide automatic demand deliveries in their main canals, they will be able to provide much better service (more flexibility and reliability) with less labor. Furthermore, the incidences of spillage and canal damage should be reduced. The second set of beneficiaries is the farmers within the irrigation districts. They must modernize their on-farm irrigation systems and practices, and in order to achieve this they must have more flexible irrigation deliveries. While this project will primarily focus on main canal automation, many main canals supply pipeline systems and direct turnouts that could be operated on a "demand" basis if the main canal is operated with downstream control.